Lab #8
Heat Engines

Equipment:

Heat Engine: The PASCO TD-8572 Heat Engine Apparatus is a simple example of a thermal engine. It consists of a nearly friction-free piston/cylinder system. The piston has a platform on which masses can be placed. A detachable air chamber, sealed by a rubber stopper, attaches to the base via plastic tubing. The chamber can be immersed in different temperature baths to create an expansion and compression cycle, lifting or dropping the platform and mass. A diagram of the heat engine is shown in the figure to the right. A rotation sensor can be connected to the platform via a string (and balance mass) to measure the relative height of the piston.

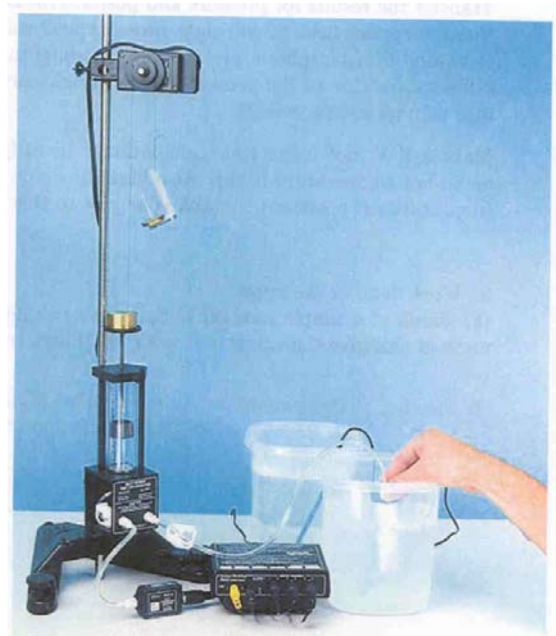

Figure 1: PASCO Heat Engine Apparatus

Procedure:

1. You will need two temperature baths to operate your engine. Start your steam generator to warm your water, and aim for a temperature of about 70-75°C. Also set up your cold water bath by adding ice to water in one of the containers. You may use the steam generator itself as the container for the hot water.
2. Attach your air chamber to one of the pressure ports. Make sure the other port is sealed (use the plastic clip inside the base).
3. Experiment with your engine to figure out the most efficient way to lift a mass (say 100g). When you develop an idea, explain it to me.
4. Set up a rotation sensor above the platform of the piston. Attach the platform of the piston to a string and suspend it on the rotation sensor, attaching a balance mass of 40-50g to the other end of the string. The string should allow your piston to sit 1-2 cm above the bottom of the piston. Note the starting position.
5. Open Data Studio and create an activity with the following sensors: (i) a temperature sensor (carefully note which one you have)

(ii) a rotation sensor: in the measurement tab, select the appropriate rack (pulley) and select position measured in m (and deselect angular position).

(iii) an absolute pressure sensor. This will be used only to determine atmospheric pressure.

(iv) a low pressure sensor.

6. Open the following graphs/meters:

(i) temperature digital meter

(ii) position graph

(iii) absolute pressure digital meter.

7. Determine the initial volume of air in your system. This includes the air in the can and in the tubing. Also calculate the added volume in the tubing connected to the 2nd pressure port. This will be needed for the initial volume for your final run (with low pressure sensor). Estimate the uncertainty.

8. Before running the engine again, release the clip on the 2nd pressure port and then attach to the low pressure sensor. This insures that the initial pressure is atmospheric pressure. Measure atmospheric pressure using the absolute pressure sensor.

9. Take data on a cycle of your engine. Note the starting volume and temperatures of the hot and cold water baths. You will obtain a position plot for the piston, which gives the relative position of the piston in time.

Analysis:

1. *P-V diagram: Measured pressure and volume values*

Transfer the results for pressure and position measured using the computer sensors to an Excel spreadsheet. Use the spreadsheet to calculate pressure and volume values as a function of time. You will need to add the value of atmospheric pressure to the value measured using the low pressure sensor (which provides a differential value of the pressure). Also think carefully about how to convert your position measurements into volume measurements.

Make a P-V plot using your calculations. Identify each part of the cycle on the graph (e.g., expansion of air in hot temperature bath). Also identify which gas process each branch appears to approximately follow (e.g., constant pressure). Attach your plot to this handout.

2. *Work done in the cycle*

(a) Think of a simple method to find the work done in the cycle. In the space below, briefly describe your method and give the calculated work. Estimate uncertainty.

(b) Find the `useful' work done to lift the mass against gravity (plus uncertainty). What percentage of the work done by the engine went into lifting the mass?

3. *Efficiency of the engine*

Use your values for pressure and volume at *A*, *B*, *C*, and *D*. Approximate the processes by the most appropriate ideal gas process (e.g., constant pressure). Assume the ideal gas law holds for air. (What value should you use for f?) Under these assumptions, find the ΔU, Q, and W values for each process. Determine $|Q_H|$ and $|Q_C|$ and use these values to calculate the efficiency of the engine. Compare to the efficiency of the *Carnot* cycle.

4. List systematic effects (and there are several!) which might influence your results and briefly indicate, if possible, in what direction these effects would change your numerical results.

SML, 2006, RAK 2005, PASCO Scientific